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ABSTRACT

We present analytical approximations for photoionization cross sections from hydrogenic and non-hydrogenic $n\ell$ - subshells. Our analytical representations satisfy the requirement that the S_2 oscillator-strength sum rule must not be violated. Using the analytical approximations for the cross sections, the photorecombination rates are given as functions of temperature in terms of hypergeometric functions.

I. INTRODUCTION

Photoionization and photorecombination have received a renewed interest in recent years, in connection with astrophysics and also in connection with high temperature laboratory plasmas. Analytical forms for photoionization cross sections are known only for hydrogenic levels, (Bethe and Salpeter, 1957; Seaton, 1959; Burgess, 1964; Fazzio and Copeland, 1985), and photorecombination rates as functions of temperature are known only either in terms of approximations to the photoionization cross sections or, in the case of hydrogenic states, in tabulated forms (Burgess, 1964). Although numerous works have addressed the problem of photorecombination using semianalytical approximations for the cross sections, in all cases known to the authors the proposed forms of the cross sections violated the S_2 oscillator sum rule. Furthermore, in many cases no distinction have been made between the ℓ subshells within a principal quantum number n. Perhaps the simplest example for a cross section that violates the S_2 sum rule is Kramer's semiclassical cross section for photoionization, which leads to a logarithmically divergent integral when used to calculate the S_2 oscillator - strength sum. In a recent work we calculated the photoionization and photorecombination rates of non-hydrogenic states by using analytical approximations for the cross sections which do not violate the S_2 sum rule (Rozsnyai and Jacobs, 1987). The purpose of this report is twofold; first we investigate the case of hydrogenic states and present analytical forms for the recombination rates as a function of temperature, and second, we analyze the differences between the hydrogenic and non-hydrogenic states. As usual, when calculating recombination rates we assume a Maxwellian distribution for the free electrons.

II. HYDROGENIC STATES

We recall Kramer's semiclassical formula for the photoionization cross section of a hydrogenic $n\ell$ level

$$\sigma^{k}_{n\ell}(\varepsilon) = \frac{2^6}{3\sqrt{3}} \pi a_o^2 \alpha \frac{n}{Z^2} \left(\frac{\varepsilon_{n\ell}}{\varepsilon}\right)^3 \qquad (1a)$$

where n stands for the principal quantum number, Z for the charge of the nucleus, a_o for the Bohr radius, α is the fine structure constant $e^2/\hbar c)$, ε and $\varepsilon_{n\ell}$ stand for the energy of the incident photon and for the threshold energy, respectively. Using $\varepsilon_{n\ell} = Z^2/2n^2$ and introducing the dimensionless relative photon energy $\omega = \varepsilon/\varepsilon_{n\ell}$ Eq. (1a) can be written as

$$\sigma^{k}_{n\ell}(\omega) = \sigma^{k}_{o} \frac{1}{n\ \varepsilon_{n\ell}} \frac{e^2}{a_o} \frac{1}{\omega^3} \qquad (1b)$$

where

$$\sigma^{k}_{o} = \frac{2^5}{3\sqrt{3}} \pi \alpha a_o{}^2 \quad .$$

The quantum mechanical cross section is conventionally expressed in terms of Kramer's cross section by

$$\sigma_{n\ell}(\omega) = \sigma^{k}_{n\ell}(\omega)\ g_{n\ell}(\omega) \quad , \qquad (2)$$

where $g_{n\ell}$ is the bound-free Gaunt factor. For hydrogenic states the Gaunt factor is given by

$$g_{n\ell}(\omega) = \frac{\sqrt{3}}{16} \frac{n}{2\ \ell + 1} \omega^3[(\ell + 1)\ Q(n\ell;\ \kappa,\ \ell + 1) + \ell\ Q(n\ell;\ \kappa\ \ell - 1) \qquad (3a)$$

where

$$Q(n\ell;\ \kappa\ell') = (1 + \kappa^2 n^2)\ [D(n\ell;\ \kappa\ell')]^2 \tag{3b}$$

with $D(n\ell;\ \kappa\ell')$ as the bound-free radial integral. The connection between the quantity κ and the reduced photon energy ω is given by (Burgess, 1964)

$$\omega = 1 + n^2 \kappa^2 \tag{3c}$$

Using the recurrence relations of the hydrogenic integrals $D(n\ell;\ \kappa\ell')$, we calculated the free-free Gaunt factors up to n = 20. Since both Kramer's cross sections and the quantum mechanical hydrogenic cross sections scale with Z as $1/Z^2$, the hydrogenic bound-free Gaunt factors are independent of Z. In contrast to Kramer's cross section, Eq. (2) with Eq. (3a) for the Gaunt factor does not violate the S_2 sum rule which requires that the integral

$$\int_0^\infty \sigma_{n\ell}(\omega)\ \omega^2\ d\omega$$

must not diverge. In fact it can be shown that the asymptotic behavior of the cross section is given by

$$\lim_{\omega\to\infty} \sigma_{n\ell}(\omega) \sim \omega^{-\ell - 7/2} \tag{4}$$

which corresponds to a $\omega^{-\ell-1/2}$ behaviour of the bound-free Gaunt factors for large photon energies. We illustrate this behaviour by showing the hydrogenic bound-free Gaunt factors for n = 2, 5, 10 and 15 in Fig. 1. It is apparent from Fig. 1, that the Gaunt factors for the different ℓ subshells diverge quite strongly as the photon energy increases and show substantial differences even at the threshold energy. We also show in Fig. 2 for a few representative n values the ℓ-averaged bound-free Gaunt factors

$$\bar{g}_n(\omega) = \frac{1}{n^2} \sum_{e} (2\ell + 1)\, g_{n\ell}(\omega) \tag{5}$$

which are conventionally used in astrophysical models.

Assuming a Maxwellian distribution of free electrons the photorecombination rate to an unoccupied $n\ell$ level is given by

$$R_{n\ell} = \frac{4\pi\, \rho_e}{(2\, m\pi)^{3/2}} \frac{\sigma_0^k}{c^2} \frac{1}{n}\, \epsilon_{n\ell}^{1/2} \frac{e^2}{a_o}\, 2(2\ell + 1) \frac{1}{\sqrt{T}}\, F_{n\ell}(T)\ (\mathrm{sec}^{-1}) \tag{6}$$

where ρ_e is the free electron density, T is the electron temperature in units of the threshold energy $\epsilon_{n\ell}$, and $F_{n\ell}(T)$ is given by the integral

$$F_{n\ell}(T) = \frac{1}{T} \int_1^{\infty} \frac{g_{n\ell}(\omega)}{\omega}\, e^{-\frac{(\omega - 1)}{T}}\, d\omega \quad . \tag{7}$$

Eq. (6) exhibits the well known property that the recombination rate is proportional to Z^2/n^3.

The interesting quantity to investigate is the function $F_{n\ell}(T)$. We notice that F(T) is finite at all temperatures. As $T \to \infty$ the integral in F(T) remains finite by virtue of the asymptotic behaviour of the Gaunt factor, and it can be shown that F(0) = g(0). To find an analytical expression for $F_{n\ell}(T)$ we approximate the integrand $g(\omega)/\omega$ in Eq. (7) by the form

$$\frac{g_{n\ell}(\omega)}{\omega} = f_{n\ell}(\omega) = \begin{cases} \dfrac{a}{(\alpha + \omega)^p} & , 1 \le \omega \le \omega_m \\[2ex] \dfrac{b}{(\beta + \omega)^{\ell + 3/2}} & , \omega_m \le \omega \le \infty \end{cases} , \tag{8}$$

where a, α, p, b, β and ω_m are best-fit parameters. Because of the Z-scaling, these parameters are independent of Z. In Table I we give the values of these parameters up to $n = 20$, and in Fig. 3 we show a comparison of the exact and approximate values of the function $g(\omega)/\omega$ for $n = 1, 5, 10$ and 15. It is evident from Fig. 3 that the approximation given by Eq. (8) is close to the exact value. Using Eq. (8) the integral in Eq. (7) can be calculated analytically. We use the formula

$$\int_{\mu}^{\infty} \frac{e^{-x}}{x^{\gamma}}\, dx = e^{-\mu}\, \mu^{1-\gamma}\, U(1,\, 2-\gamma,\, \mu) \quad , \tag{9}$$

where the U-s stand for the confluent hypergeometric functions of the second kind, which are easy to compute. Using Eqs. (9) and (8) the integral $F_{n\ell}(T)$ is given by

$$F_{n\ell}(T) = \frac{a}{T}\{(1+\alpha)^{1-p}\, U(1,\, 2-p,\, \frac{1+\alpha}{T}) - e^{-\frac{(\omega_m - 1)}{T}}\, (\omega_m + T)^{1-p}$$

$$\times\, U(1,\, 2-p,\, \frac{\omega_m + \alpha}{T})\} + \frac{b}{T}\, e^{-\frac{\omega_m - 1}{T}}\, (\beta + \omega_m)^{-\ell-1/2}\, U(1,\, \frac{1}{2} - \ell,\, \frac{\beta + \omega_m}{T}) \ . \tag{10}$$

In Fig. 4 the full line shows the quantity $2(2\ell + 1) \times F_{n\ell}(T)$ obtained by numerically integrating the integrand in Eq. (7) and the dotted line was obtained by using the analytical form of Eq. (10). It is evident from the graphs, that the analytical form of $F_{n\ell}(T)$ is bound to be accurate. We compare our results with those based on Kramer's formula, which assumes that the Gaunt factor is one, by showing for some representative n-values the ℓ averaged values of $F_{n\ell}(T)$

$$\bar{F}_n(T) = \frac{1}{n^2} \sum_{\ell} (2\ell + 1)\, F_{n\ell}(T) \tag{11}$$

in Fig. 5. In Fig. 5 Kramer's values are marked by the letter K. As is evident, the two sets of curves are quite close, but this occurs only after l averaging.

III. NON-HYDROGENIC STATES

The states of many electron atoms or ions are non-hydrogenic and the photoionization cross sections must be calculated numerically. In the case of partial ionization one can attempt to use the hydrogenic approximation to the cross sections by inserting in Eq. (1b) the actual threshold energies $\varepsilon_{n\ell}$ and retaining the hydrogenic bound-free Gaunt factors in Eq. (2). In the case of neutral atoms, especially when Cooper minima occur this approximation is obviously inadequate. If the photoionization cross section is a monotonically decreasing function of the photon energy, then an analytical approximation to the cross section analogous to Eq. (8), as was presented in Ref. 5, may be feasible. In the remainder of this paper we present calculations for the neon-like FeXVII ion as an example of the application of the analytical approximation to the cross sections.

In accordance with Ref. 4, we use an analytical approximation for the photoionization cross sections given by

$$\sigma_{n\ell}(\omega) = \frac{A}{\omega^{p}} \qquad ; \qquad 1 \le \omega \le \omega_m$$

$$= \frac{B}{(\omega + \beta)^{\ell + 7/2}} \qquad \omega_m \le \omega \le \infty \tag{12}$$

where as before, the photon energies are given in units of the threshold energy. Introducing

$$A = a\,K \quad ; \quad B = b\,K$$

where

$$K = \frac{2^5}{3\sqrt{3}}\,\pi\,\alpha\,e^2 a_o \frac{1}{n\,\epsilon_{n\ell}}\ (cm^2) \tag{13}$$

the bound-free Gaunt factor is given by

$$g_{n\ell}(\omega) = \frac{a}{\omega^{p-3}} \qquad 1 < \omega < \omega_m$$

$$\frac{b\,\omega^3}{(\omega + \beta)^{\ell+7/2}} \qquad \omega_m \le \omega \le \infty \quad . \tag{14}$$

Using Eqs. (9) and (14), the integral $F_{n\ell}(T)$ is given by

$$F_{n\ell}(T) = \frac{a}{T}\,\{U(1,\ 4 - p,\ \frac{1}{T}) - e^{-\frac{\omega_m - 1}{T}}\,\omega_m^{3-p}\,U(1,\ 4 - p,\ \frac{\omega_m}{T})\}$$

$$+ \frac{b}{T}\,e^{-\frac{\omega_m - 1}{T}}\,\{(\omega_m + \beta)^{-\ell-1/2}\,U(1,\ \frac{1}{2} - \ell,\ \frac{\omega_m + \beta}{T})$$

$$- 2\beta(\omega_m + \beta)^{-\ell-3/2}\,U(1,\ -\ell - \frac{1}{2},\ \frac{\omega_m + \beta}{T})$$

$$+ \beta^2(\omega_m + \beta)^{-\ell-5/2}\,U(1,\ -\ell - \frac{3}{2},\ \frac{\omega_m + \beta}{T})\} \tag{15}$$

In Table II we present the results for the one - electron $n\ell$ states of the FeXVII ion from n = 1 to 8. We include the results for the occupied n = 1 and 2 states, because for the photoionization rates the same integral has to be calculated. The cross sections are normalized to one-electron occupancies. The first and second column give n and 1, respectively, the third the threshold energy in atomic units (27,204 eV), the fourth to eight columns give the parameters a, p, b, β and ω_m which are dimensionless.

In the last column we give the "hydrogenic factors" which multiply the hydrogenic bound-free Gaunt factors in Eq. (2) in such a way that the cross sections at threshold agree with the computed Hartree-Slater values. A graphic illustration of our results is presented in Fig. 6. In the left frames of Fig. 6 the full lines show the numerically computed photoionization cross sections based on the self-consistent Hartree- Slater state of the FeXVII ion. For the occupied n = 1 and 2 states our cross sections are in close agreement with those of Reilman and Manson,[5] for the unoccupied states we have no data with which we can compare our results. In the same frames the dotted curves marked by A-s show the results of our analytic approximation given by Eq. (12) and using the parameters of Table II. The dotted curves marked by H-s are the results of the generalized hydrogenic formula given by Eq. (2) using the actual threshold energies in column three of Table II and the "hydrogenic factors" in the last column of the same table. The right side frames of Fig. 6 show the integrals $F_{n\ell}(T)$ computed in various ways. The full curves are the results of numerical integrations using the Hartree-Slater self-consistent wave functions. The dotted curves marked by A-s are the results of the analytic approximation given by Eq. (15) and the dotted curves marked by Z and H are hydrogenic approximations. The curve Z uses the "hydrogenic factor" gff of Table II, and the H curve corresponds gff = 1. It is interesting to note, that even when the threshold energies suggest that the states are expected to be hydrogenic, like for the n = 8 states, the cross sections are significantly reduced from the hydrogenic values, as indicated by the last column of Table II.

CONCLUSION

The analytical approximation of hydrogenic photoionization cross sections presented in this paper makes it possible to express the photorecombination and photoionization rates in analytical forms which are Z scaled, thus universal. The method can be extended to non-hydrogenic states where the cross sections are monotonically decreasing functions of the photon energy. Work is under way to establish tables for ionic levels for cases when the method presented in this paper is applicable.

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1221M/596M

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FIGURE CAPTIONS

Fig. 1. Bound-free Gaunt factors for hydrogenic levels for $n = 2, 5, 10$ and 15. The ℓ-substates are marked on the curves.

Fig. 2. Bound-free hydrogenic Gaunt Factors averaged over ℓ for $n = 1, 5, 10$ and 15.

Fig. 3. The function $g(\omega)/\omega$ for hydrogenic levels for $n = 1, 5, 10$ and 15. Full curve, -exact hydrogenic values, x- approximation by Eq. (8) with the values of Table I of the text.

Fig. 4. The function $2(2\ell + 1)F_{n\ell}(T)$ for hydrogenic states for $n = 1, 5, 10$ and 15. Full curve, -exact hydrogenic values, dotted curve,- Eq. (10) with the values of Table I of the text. The numbers next to the curves indicate the ℓ values. The label κT/OMTR stands for the temperature T in units of the threshold energy.

Fig. 5. The function F(T) averaged over ℓ for hydrogenic states for $n = 1, 5, 10$ and 15. Full curve, -hydrogenic values, K,- obtained from Kramer's cross sections.

Fig. 6. The frames on the left side are photoionization cross sections (in a.u. -s) and the frames on the right are the functions F(T) for the one- electron levels (occupied or empty) of the FeXVII ion. The principal and angular quantum numbers together with the threshold energy and the "hydrogenic factor" gff are indicated in the frames. The full curves are the results of numerical computations using the Hartree-Slater self-consistent wave functions. Full explanation is given in the text.

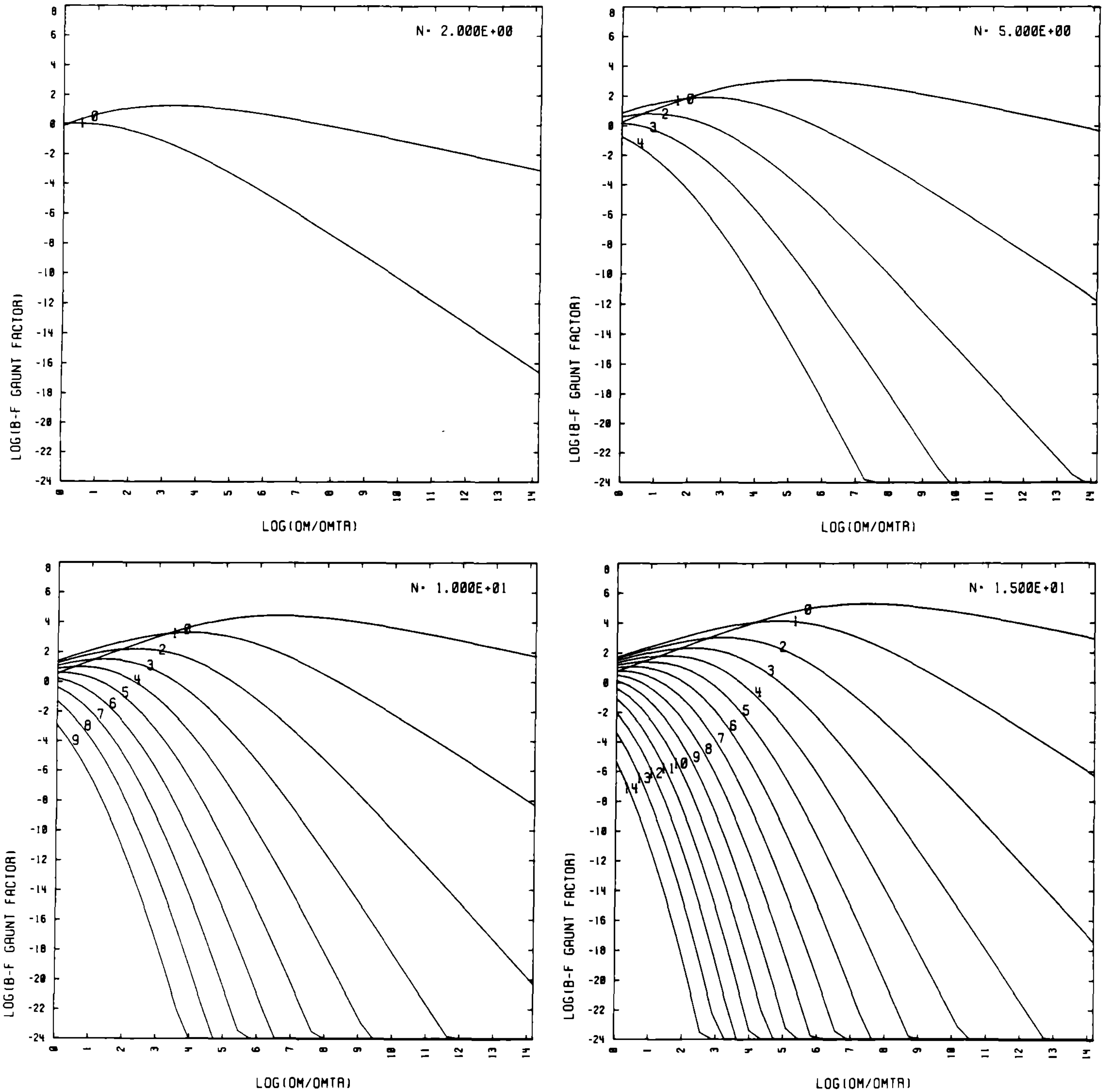

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Fig. 1

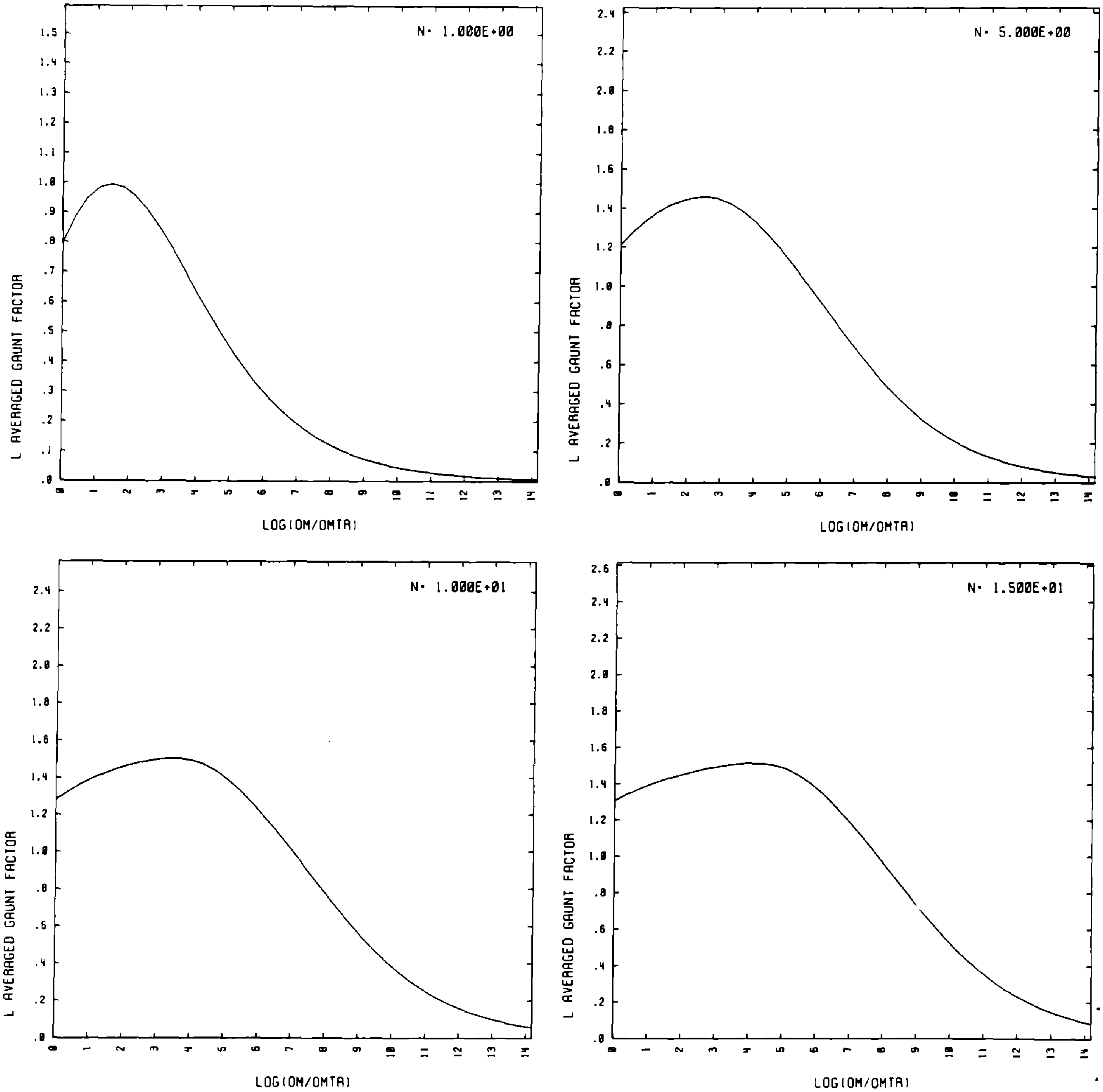
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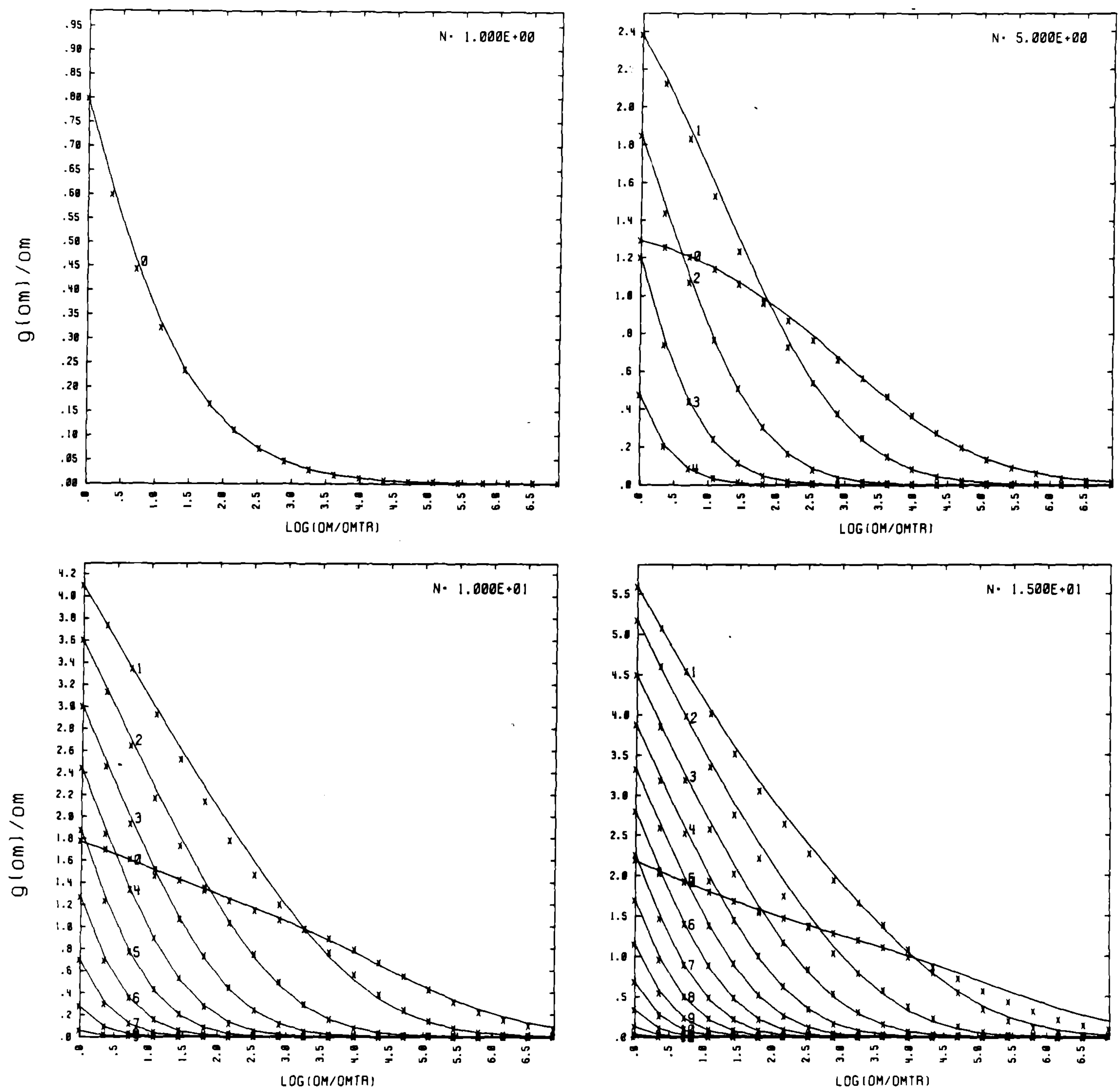
Fig. 2



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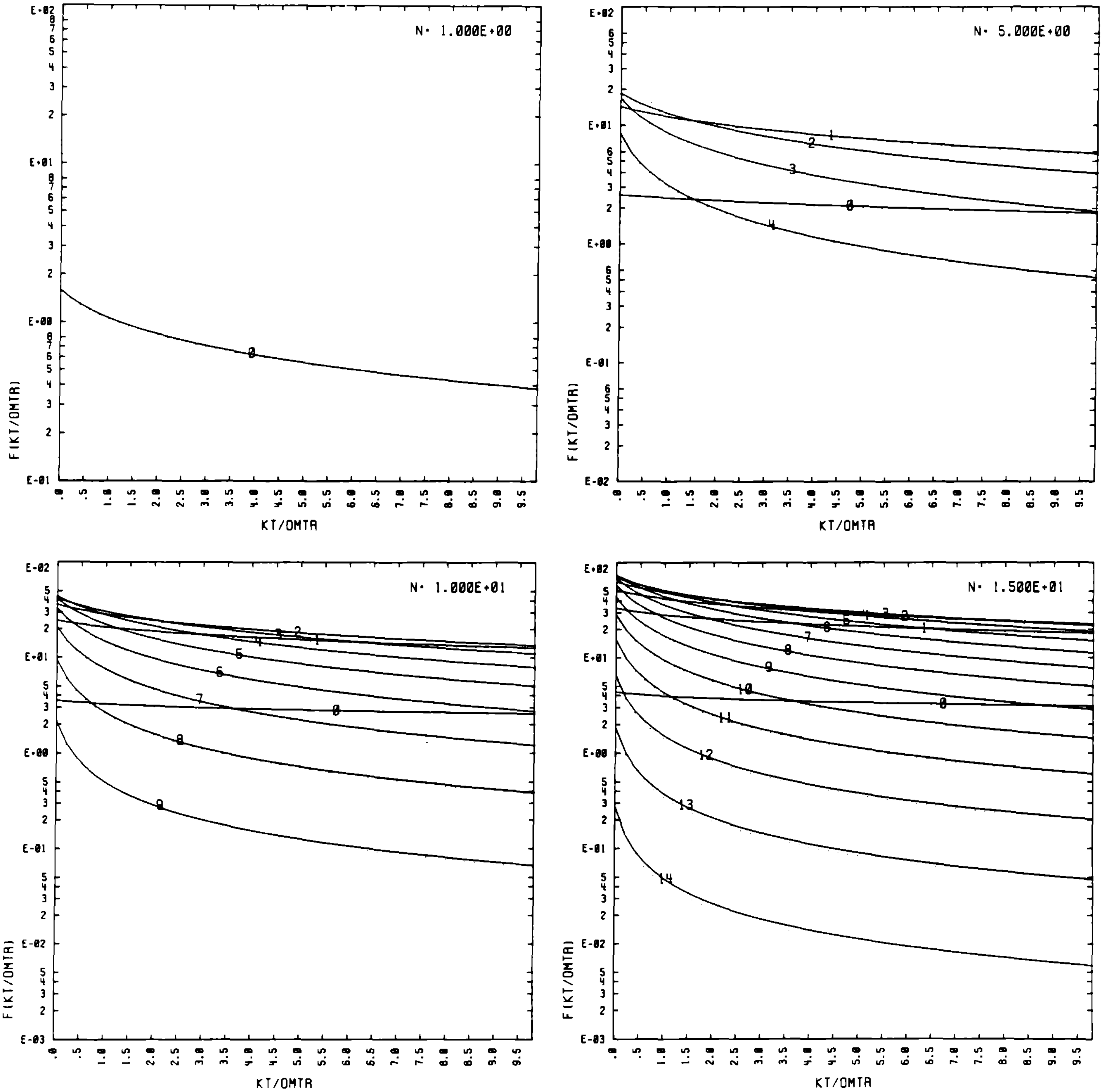

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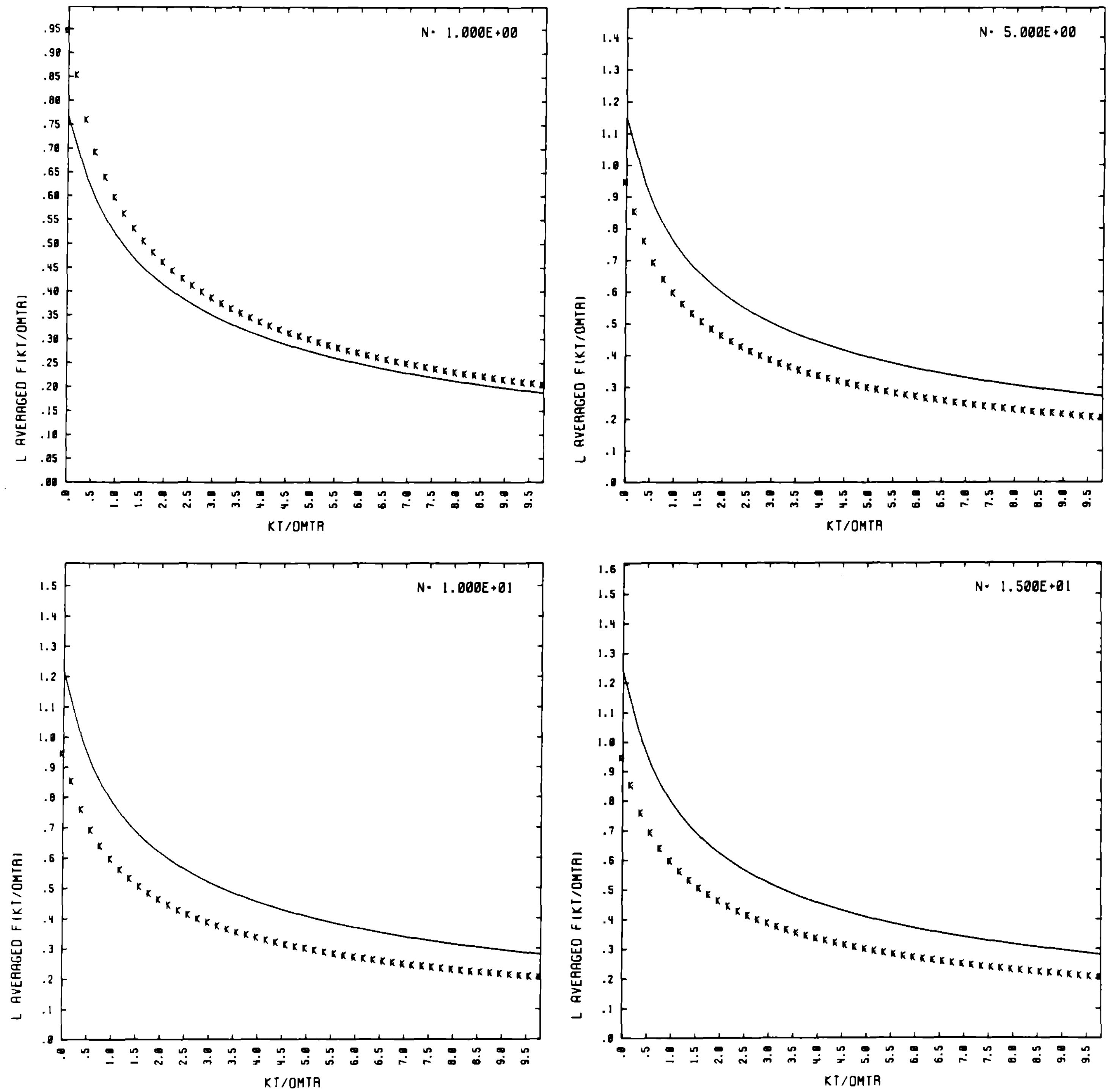

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L AVERAGED F(KT/OMTR)
KT/OMTR

Fig. 5

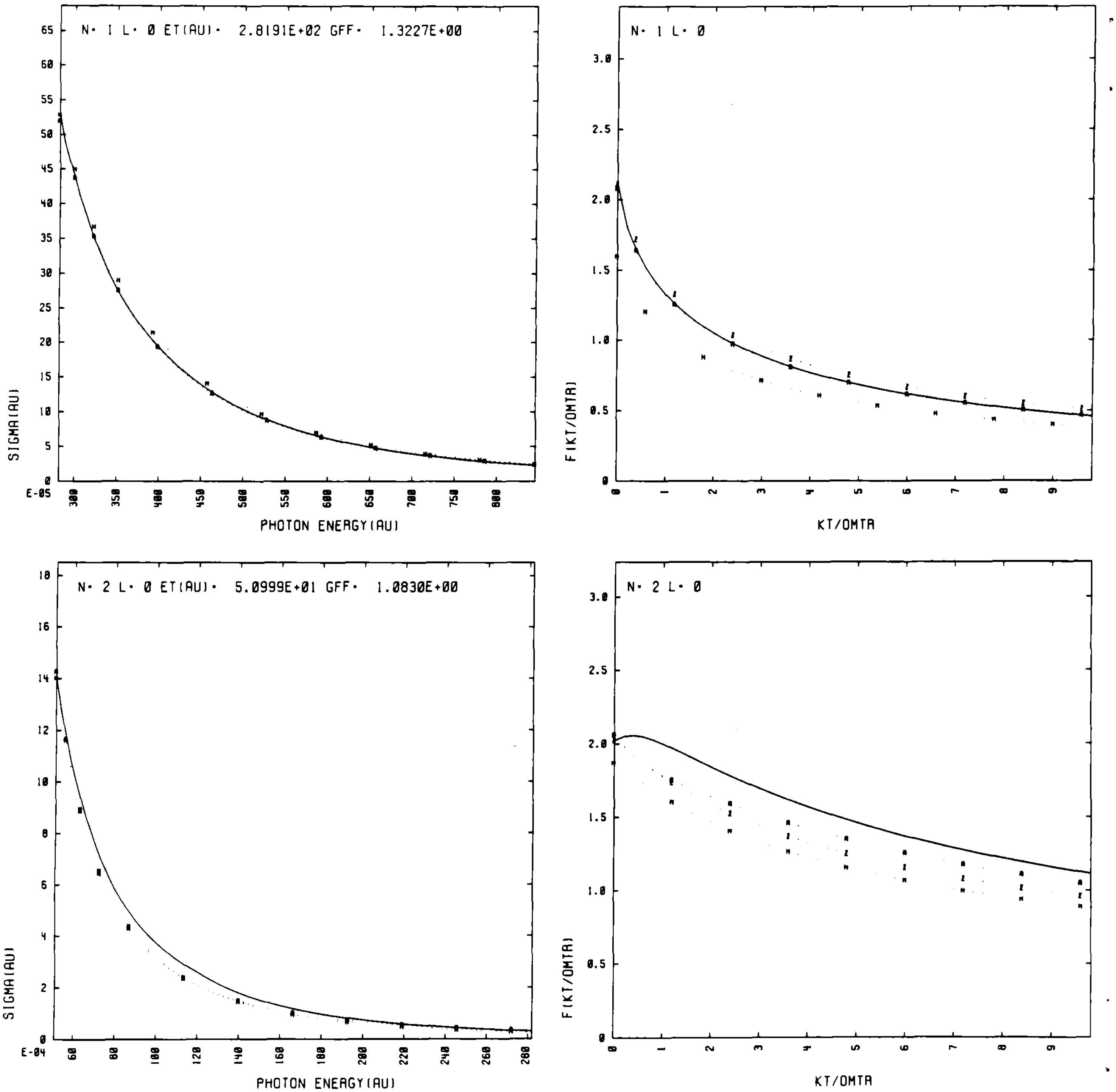
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Fig. 6

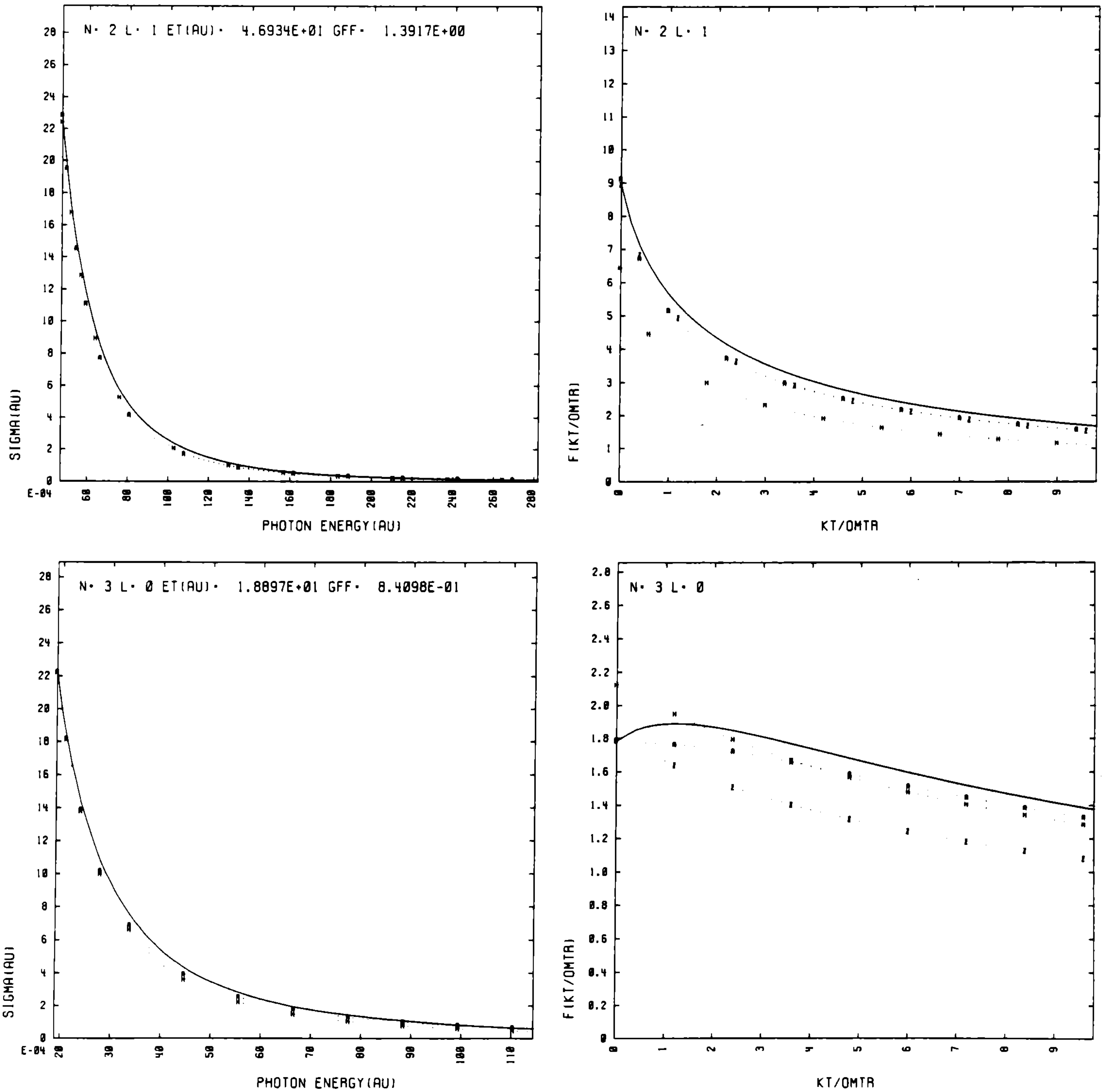
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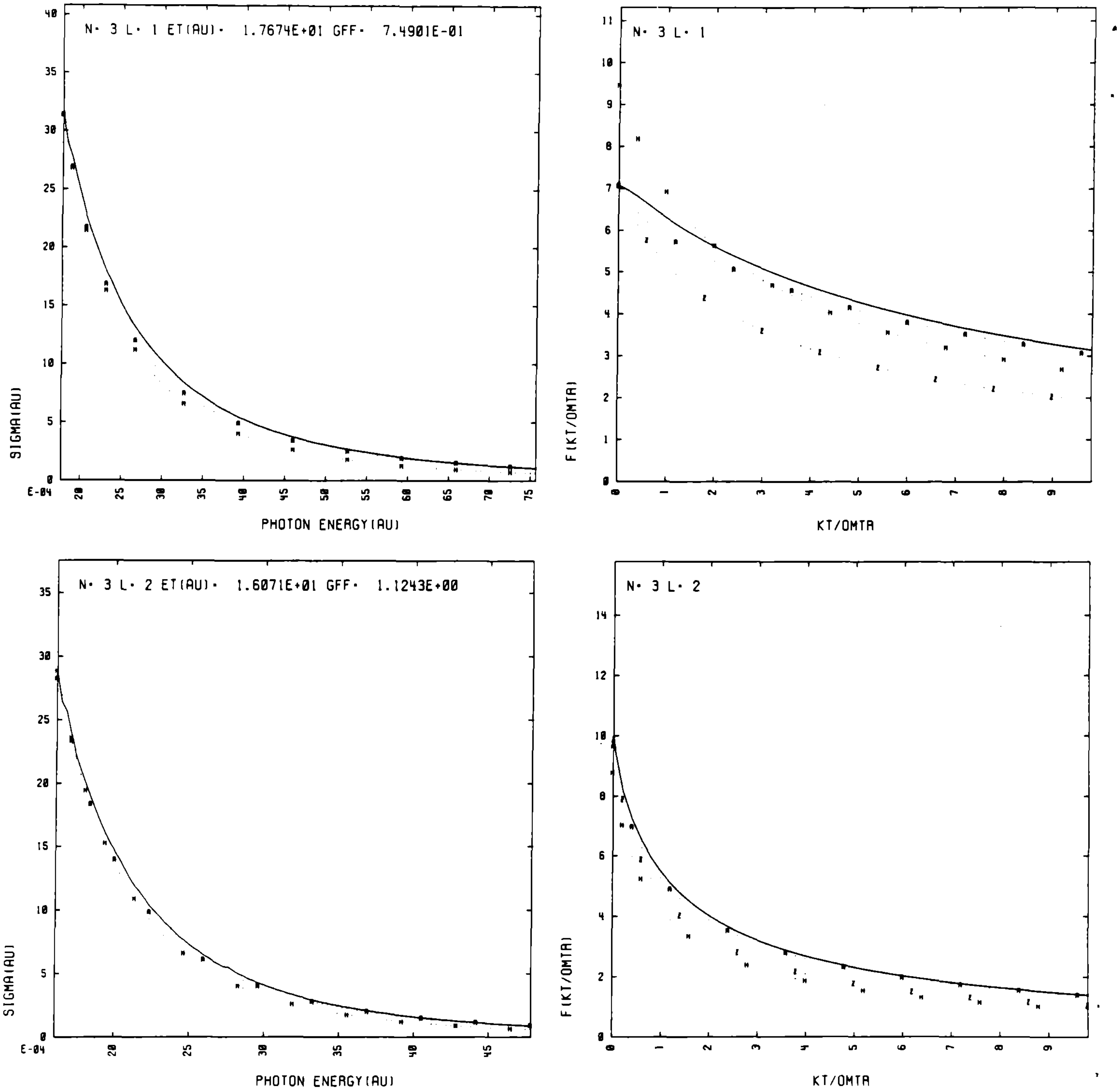
Fig. 6 (cont.)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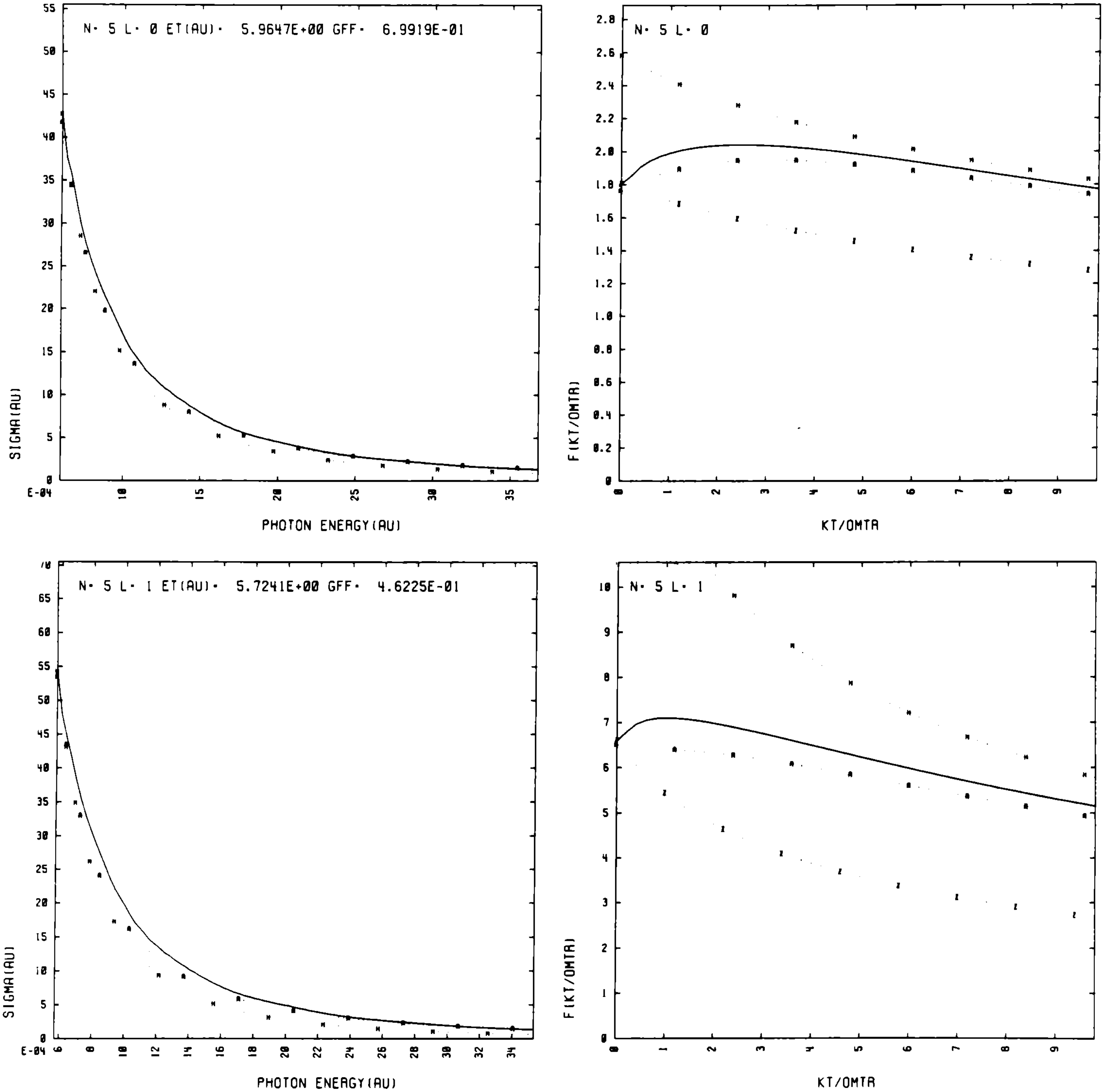

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Fig. 6 (cont.)

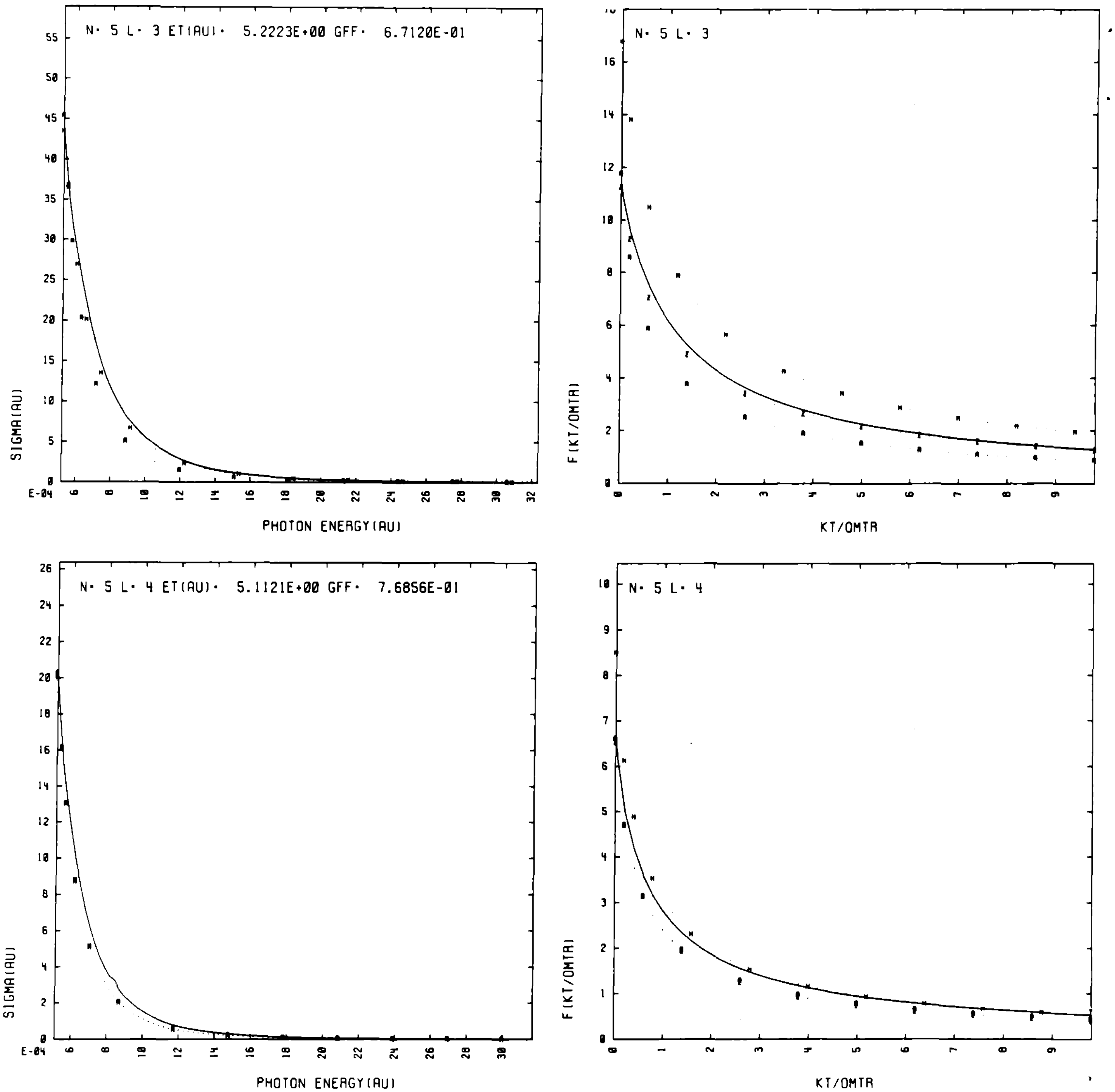
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Fig. 6 (cont.)

Table I. Analytical approximation of $g(\omega)/\omega$ for hydrogenic states.

n	l	a	p	α	b	β	ω_m
1	0	9.8842961e-01	9.5707824e-01	2.5172354e-01	4.4058029e+00	2.8231311e+00	4.2812285e+00
2	0	1.1792337e+01	1.2783600e+00	6.2650796e+00	3.2451554e+01	1.1922442e+01	2.6365069e+01
2	1	1.1028444e+00	1.0455504e+00	2.8813744e-02	2.8643737e+01	2.9472086e+00	2.0691130e+00
3	0	4.8389398e+01	1.3834103e+00	1.4814942e+01	8.4278442e+01	1.8285472e+01	2.6365069e+01
3	1	4.6015991e+00	1.2037640e+00	1.4385699e+00	2.7425189e+02	7.5977580e+00	4.2812285e+00
3	2	9.1559806e-01	1.5618978e+00	2.8099630e-02	6.4794014e+01	2.6304546e+00	2.0691130e+00
4	0	1.3573396e+01	9.4557736e-01	1.2246281e+01	2.0558457e+02	3.4885366e+01	2.6365069e+01
4	1	8.8609535e+00	1.1925185e+00	2.4955308e+00	1.3512920e+03	1.4943962e+01	8.8583454e+00
4	2	2.4326859e+00	1.3339723e+00	4.9811686e-01	5.4855771e+02	4.6666373e+00	2.0691130e+00
4	3	6.9488065e-01	1.9997057e+00	2.5361923e-02	1.6974676e+02	2.6441490e+00	2.0691130e+00
5	0	4.5972177e+00	5.9838290e-01	7.3629425e+00	4.3533721e+02	5.8182831e+01	2.6365069e+01
5	1	9.7056639e+00	1.0561843e+00	2.7857238e+00	4.3880805e+03	2.4012581e+01	1.2742209e+01
5	2	5.2863833e+00	1.3663696e+00	1.1600568e+00	2.9413209e+03	7.6191076e+00	2.9762973e+00
5	3	2.0508495e+00	1.7438584e+00	3.6127299e-01	1.6887494e+03	4.2024609e+00	2.0691130e+00
5	4	5.0590643e-01	2.4195397e+00	2.9040385e-02	4.5388066e+02	2.7003246e+00	2.0691130e+00
6	0	2.8736155e+00	4.2361947e-01	4.5103813e+00	7.6823205e+02	8.2962237e+01	2.6365069e+01
6	1	9.8679391e+00	9.5302961e-01	2.8268133e+00	1.2351179e+04	3.7167078e+01	1.8328917e+01
6	2	7.9013491e+00	1.3187495e+00	1.6127502e+00	1.1529898e+04	1.1361565e+01	4.2812285e+00
6	3	3.4030009e+00	1.5154958e+00	6.2346146e-01	8.7631346e+03	5.9260166e+00	2.0691130e+00
6	4	1.6760271e+00	2.1515273e+00	2.9509436e-01	5.2172788e+03	3.9745661e+00	2.0691130e+00
6	5	3.5685878e-01	2.8343347e+00	3.4689882e-02	1.2009618e+03	2.7555531e+00	2.0691130e+00
7	0	2.3496511e+00	3.3171689e-01	2.9128062e+00	1.1676758e+03	1.0602739e+02	2.6365069e+01
7	1	1.0201613e+01	8.8790384e-01	2.8260670e+00	3.1241332e+04	5.5826084e+01	2.6365069e+01
7	2	7.1699857e+00	1.0993277e+00	1.5291069e+00	2.8210315e+04	1.4217508e+01	4.2812285e+00
7	3	4.1618650e+00	1.2958668e+00	7.5335184e-01	3.1339819e+04	7.7321193e+00	2.0691130e+00
7	4	3.1399504e+00	1.9158037e+00	5.2822690e-01	3.1749691e+04	5.3874803e+00	2.0691130e+00
7	5	1.3227207e+00	2.5601042e+00	2.5651019e-01	1.5698463e+04	3.8355492e+00	2.0691130e+00
7	6	2.4536159e-01	3.2474987e+00	4.0495348e-02	3.1247654e+03	2.8029637e+00	2.0691130e+00
8	0	2.1517760e+00	2.7905785e-01	1.9565383e+00	1.5898075e+03	1.2587007e+02	2.6365069e+01
8	1	8.9141668e+00	7.7348612e-01	2.4251235e+00	5.5361197e+04	6.6688290e+01	2.6365069e+01
8	2	8.4783079e+00	1.0621360e+00	1.7183014e+00	8.4346771e+04	1.9797032e+01	6.1582953e+00
8	3	7.0937963e+00	1.3847772e+00	1.2168604e+00	1.2401665e+05	1.0649873e+01	2.9762973e+00
8	4	4.3320977e+00	1.6934970e+00	6.9386273e-01	1.3504603e+05	6.9042520e+00	2.0691130e+00
8	5	2.7645291e+00	2.3188395e+00	4.6265837e-01	1.0916438e+05	5.0277618e+00	2.0691130e+00
8	6	1.0102198e+00	2.9697488e+00	2.3124628e-01	4.5814475e+04	3.7403664e+00	2.0691130e+00
8	7	1.6520881e-01	3.6600979e+00	4.5867853e-02	7.9957177e+03	2.8425964e+00	2.0691130e+00
9	0	2.0762118e+00	2.4678324e-01	1.3456995e+00	1.9993389e+03	1.4206676e+02	2.6365069e+01
9	1	8.1345877e+00	6.8667039e-01	2.0651968e+00	8.9022289e+04	7.7142619e+01	2.6365069e+01
9	2	9.8317151e+00	1.0387021e+00	1.8877523e+00	2.3843190e+05	2.7351597e+01	8.8583454e+00
9	3	6.6228407e+00	1.1832249e+00	1.1466829e+00	2.9662997e+05	1.2704078e+01	2.9762973e+00
9	4	4.9577047e+00	1.4822862e+00	7.7426707e-01	4.4722682e+05	8.4812045e+00	2.0691130e+00
9	5	4.2553065e+00	2.0948371e+00	6.3356831e-01	5.3397089e+05	6.3169464e+00	2.0691130e+00
9	6	2.3313344e+00	2.7240027e+00	4.1424321e-01	3.5744794e+05	4.7683147e+00	2.0691130e+00
9	7	7.4967468e-01	3.3801938e+00	2.1339249e-01	1.2999578e+05	3.6705865e+00	2.0691130e+00
9	8	1.0933846e-01	4.0725077e+00	5.0664137e-02	2.0155638e+04	2.8757230e+00	2.0691130e+00
10	0	2.0563667e+00	2.2604048e-01	9.3474604e-01	2.3744743e+03	1.5479595e+02	2.6365069e+01

Table I. (cont.)

n	l	a	p	α	b	β	ω_m
10	1	7.6730343e+00	6.2031976e-01	1.7570560e+00	1.3244186e+05	8.6972144e+01	2.6365069e+01
10	2	8.7196598e+00	9.1049015e-01	1.6444109e+00	4.2849845e+05	3.1515125e+01	8.8583454e+00
10	3	8.9248116e+00	1.2191020e+00	1.4475180e+00	9.7721800e+05	1.6864959e+01	4.2812285e+00
10	4	5.1120327e+00	1.2888119e+00	7.7572031e-01	1.2208566e+06	1.0071203e+01	2.0691130e+00
10	5	5.3751745e+00	1.8814239e+00	7.5344552e-01	2.0487775e+06	7.6823470e+00	2.0691130e+00
10	6	3.9553889e+00	2.4977741e+00	5.7820095e-01	1.9654785e+06	5.8799062e+00	2.0691130e+00
10	7	1.8936748e+00	3.1307080e+00	3.7703064e-01	1.1227356e+06	4.5722668e+00	2.0691130e+00
10	8	5.4277583e-01	3.7911994e+00	2.0009019e-01	3.5993742e+05	3.6170639e+00	2.0691130e+00
10	9	7.1330791e-02	4.4848702e+00	5.4894831e-02	5.0150745e+04	2.9036244e+00	2.0691130e+00
11	0	2.0653225e+00	2.1228085e-01	6.4682204e-01	2.7051996e+03	1.6450395e+02	2.6365069e+01
11	1	7.4113293e+00	5.6897158e-01	1.4977934e+00	1.8509958e+05	9.6061355e+01	2.6365069e+01
11	2	1.0196196e+01	9.1954728e-01	1.8273681e+00	1.1025212e+06	4.2712818e+01	1.2742209e+01
11	3	7.9511144e+00	1.0633485e+00	1.2836432e+00	1.9129941e+06	1.9268833e+01	4.2812285e+00
11	4	5.0366445e+00	1.1201818e+00	7.2086299e-01	2.8490377e+06	1.1629438e+01	2.0691130e+00
11	5	5.9587334e+00	1.6788381e+00	8.1544934e-01	6.5260939e+06	9.0991202e+00	2.0691130e+00
11	6	5.4870318e+00	2.2837627e+00	7.1227894e-01	8.5072965e+06	7.0651281e+00	2.0691130e+00
11	7	3.5050812e+00	2.9017283e+00	5.3000622e-01	6.8310334e+06	5.5444576e+00	2.0691130e+00
11	8	1.4896742e+00	3.5385450e+00	3.4761263e-01	3.4058324e+06	4.4191169e+00	2.0691130e+00
11	9	3.8479231e-01	4.2025985e+00	1.8978957e-01	9.7591197e+05	3.5746516e+00	2.0691130e+00
11	10	4.5975860e-02	4.8972405e+00	5.8618288e-02	1.2338693e+05	2.9273559e+00	2.0691130e+00
12	0	2.0905381e+00	2.0298209e-01	4.3849369e-01	2.9895078e+03	1.7170829e+02	2.6365069e+01
12	1	7.2788391e+00	5.2868235e-01	1.2807265e+00	2.4594273e+05	1.0436464e+02	2.6365069e+01
12	2	9.3917083e+00	8.3106497e-01	1.6045382e+00	1.7601922e+06	4.7678596e+01	1.2742209e+01
12	3	1.0058444e+01	1.1009439e+00	1.5389830e+00	5.8445831e+06	2.5303573e+01	6.1582953e+00
12	4	7.9515305e+00	1.2673298e+00	1.1389959e+00	1.0165021e+07	1.4883389e+01	2.9762973e+00
12	5	6.0990044e+00	1.4909997e+00	8.2327299e-01	1.7865873e+07	1.0540218e+01	2.0691130e+00
12	6	6.6068512e+00	2.0790580e+00	8.0839602e-01	3.0708408e+07	8.3112215e+00	2.0691130e+00
12	7	5.2922926e+00	2.6865802e+00	6.6529918e-01	3.2747645e+07	6.5822214e+00	2.0691130e+00
12	8	2.9834618e+00	3.3065728e+00	4.8897300e-01	2.2667084e+07	5.2804355e+00	2.0691130e+00
12	9	1.1402668e+00	3.9472332e+00	3.2383508e-01	1.0034164e+07	4.2963469e+00	2.0691130e+00
12	10	2.6791911e-01	4.6142797e+00	1.8157585e-01	2.5988399e+06	3.5401962e+00	2.0691130e+00
12	11	2.9330030e-02	5.3096390e+00	6.1902070e-02	3.0062904e+05	2.9477419e+00	2.0691130e+00
13	0	2.1255473e+00	1.9665587e-01	2.8377450e-01	3.2299578e+03	1.7689998e+02	2.6365069e+01
13	1	7.2327136e+00	4.9664293e-01	1.0988779e+00	3.1361483e+05	1.1188288e+02	2.6365069e+01
13	2	1.1076543e+01	8.5746457e-01	1.8210739e+00	4.2557713e+06	6.3919343e+01	1.8328917e+01
13	3	9.0897285e+00	9.8524206e-01	1.3583676e+00	1.0140983e+07	2.8173352e+01	6.1582953e+00
13	4	7.2845902e+00	1.1186530e+00	1.0200895e+00	2.0076569e+07	1.6672448e+01	2.9762973e+00
13	5	5.9892822e+00	1.3221836e+00	7.8835449e-01	4.3042994e+07	1.1978511e+01	2.0691130e+00
13	6	7.2034414e+00	1.8840766e+00	8.6309768e-01	9.5717764e+07	9.6032254e+00	2.0691130e+00
13	7	6.9042620e+00	2.4813449e+00	7.7657176e-01	1.3119920e+08	7.6789558e+00	2.0691130e+00
13	8	4.8617074e+00	3.0895027e+00	6.1961971e-01	1.1880523e+08	6.1985480e+00	2.0691130e+00
13	9	2.4547740e+00	3.7122538e+00	4.5423339e-01	7.2413685e+07	5.0680975e+00	2.0691130e+00
13	10	8.5260259e-01	4.3565768e+00	3.0425877e-01	2.8840090e+07	4.1958461e+00	2.0691130e+00
13	11	1.8366871e-01	5.0261680e+00	1.7487306e-01	6.8141783e+06	3.5116447e+00	2.0691130e+00
13	12	1.8546045e-02	5.7220718e+00	6.4809559e-02	7.2629896e+05	2.9654191e+00	2.0691130e+00
14	0	2.1667500e+00	1.9237800e-01	1.6637057e-01	3.4312596e+03	1.8050454e+02	2.6365069e+01
14	1	7.2461674e+00	4.7084419e-01	9.4605534e-01	3.8665368e+05	1.1864641e+02	2.6365069e+01

Table I. (cont.)

n	l	a	p	α	b	β	ω_m
14	2	1.0439733e+01	7.9185290e-01	1.6261073e+00	6.2864370e+06	6.9872549e+01	1.8328917e+01
14	3	1.1340476e+01	1.0320785e+00	1.6197220e+00	2.9555294e+07	3.6827425e+01	8.8583454e+00
14	4	1.0173673e+01	1.2136056e+00	1.3561752e+00	6.8622646e+07	2.1267205e+01	4.2812285e+00
14	5	5.7922497e+00	1.1749246e+00	7.2502779e-01	9.2901948e+07	1.3388828e+01	2.0691130e+00
14	6	7.3545801e+00	1.7011217e+00	8.7809395e-01	2.6366781e+08	1.0924697e+01	2.0691130e+00
14	7	8.0817690e+00	2.2844448e+00	8.5918412e-01	4.5520153e+08	8.8265432e+00	2.0691130e+00
14	8	6.8273904e+00	2.8833724e+00	7.3507178e-01	5.2064502e+08	7.1699834e+00	2.0691130e+00
14	9	4.2871265e+00	3.4927229e+00	5.7796589e-01	4.1103161e+08	5.8886692e+00	2.0691130e+00
14	10	1.9624044e+00	4.1187077e+00	4.2475203e-01	2.2412882e+08	4.8941021e+00	2.0691130e+00
14	11	6.2474537e-01	4.7664347e+00	2.8788607e-01	8.1156502e+07	4.1121293e+00	2.0691130e+00
14	12	1.2422576e-01	5.4382121e+00	1.6929988e-01	1.7628005e+07	3.4875981e+00	2.0691130e+00
14	13	1.1637349e-02	6.1345392e+00	6.7396048e-02	1.7417423e+06	2.9808802e+00	2.0691130e+00
15	0	2.2120147e+00	1.8954974e-01	7.5662304e-02	3.5988084e+03	1.8287340e+02	2.6365069e+01
15	1	7.3018994e+00	4.4983338e-01	8.1707427e-01	4.6363611e+05	1.2470278e+02	2.6365069e+01
15	2	1.2382817e+01	8.2794217e-01	1.8757797e+00	1.4483944e+07	9.3018838e+01	2.6365069e+01
15	3	1.0436232e+01	9.4334606e-01	1.4462884e+00	4.7313669e+07	4.0297372e+01	8.8583454e+00
15	4	9.1974851e+00	1.0911490e+00	1.2110917e+00	1.2268028e+08	2.3403130e+01	4.2812285e+00
15	5	9.7236455e+00	1.3744406e+00	1.1858079e+00	3.5340523e+08	1.6707117e+01	2.9762973e+00
15	6	7.2220532e+00	1.5329049e+00	8.5928202e-01	6.5264870e+08	1.2258561e+01	2.0691130e+00
15	7	8.7346821e+00	2.0961029e+00	9.1097422e-01	1.4002782e+09	1.0015571e+01	2.0691130e+00
15	8	8.5657847e+00	2.6857984e+00	8.3138622e-01	1.9784566e+09	8.1903102e+00	2.0691130e+00
15	9	6.4376680e+00	3.2849807e+00	6.9193769e-01	1.9497625e+09	6.7562150e+00	2.0691130e+00
15	10	3.6524630e+00	3.8964485e+00	5.4099306e-01	1.3677286e+09	5.6343687e+00	2.0691130e+00
15	11	1.5304665e+00	4.5258574e+00	3.9958178e-01	6.7535045e+08	4.7491939e+00	2.0691130e+00
15	12	4.4979835e-01	5.1767034e+00	2.7400572e-01	2.2423942e+08	4.0413592e+00	2.0691130e+00
15	13	8.3036432e-02	5.8503761e+00	1.6459352e-01	4.5069662e+07	3.4670685e+00	2.0691130e+00
15	14	7.2533236e-03	6.5470388e+00	6.9708353e-02	4.1497484e+06	2.9945092e+00	2.0691130e+00
16	0	2.2600138e+00	1.8776924e-01	4.5005744e-03	3.7378891e+03	1.8428900e+02	2.6365069e+01
16	1	7.3883773e+00	4.3254567e-01	7.0769420e-01	5.4326892e+05	1.3010837e+02	2.6365069e+01
16	2	1.1821216e+01	7.7599590e-01	1.7034538e+00	2.0293096e+07	1.0023332e+02	2.6365069e+01
16	3	9.8120580e+00	8.6989856e-01	1.2881103e+00	7.1883777e+07	4.3629442e+01	8.8583454e+00
16	4	8.5108719e+00	9.8965641e-01	1.0712182e+00	2.0550662e+08	2.5464910e+01	4.2812285e+00
16	5	8.8466675e+00	1.2353738e+00	1.0797854e+00	6.8467093e+08	1.8365046e+01	2.9762973e+00
16	6	6.9587249e+00	1.3814629e+00	8.1485028e-01	1.4703104e+09	1.3588002e+01	2.0691130e+00
16	7	8.9233240e+00	1.9176573e+00	9.3252576e-01	3.8830300e+09	1.1235626e+01	2.0691130e+00
16	8	9.8520246e+00	2.4957462e+00	9.0563584e-01	6.6782367e+09	9.2541993e+00	2.0691130e+00
16	9	8.6145368e+00	3.0864618e+00	7.9318289e-01	8.0214091e+09	7.6682850e+00	2.0691130e+00
16	10	5.8311684e+00	3.6865258e+00	6.5083007e-01	6.9679318e+09	6.4156628e+00	2.0691130e+00
16	11	3.0218782e+00	4.3007961e+00	5.0850637e-01	4.4051232e+09	5.4225795e+00	2.0691130e+00
16	12	1.1682726e+00	4.9336221e+00	3.7793084e-01	1.9886700e+09	4.6267974e+00	2.0691130e+00
16	13	3.1888501e-01	5.5873046e+00	2.6209858e-01	6.0978910e+08	3.9807751e+00	2.0691130e+00
16	14	5.4931015e-02	6.2626342e+00	1.6056685e-01	1.1404289e+08	3.4493376e+00	2.0691130e+00
16	15	4.4941239e-03	6.9595676e+00	7.1785641e-02	9.8299810e+06	3.0066086e+00	2.0691130e+00
17	0	2.3098843e+00	1.8675862e-01	-5.2061439e-02	3.8532995e+03	1.8497463e+02	2.6365069e+01
17	1	7.4976873e+00	4.1818952e-01	6.1447753e-01	6.2443527e+05	1.3492273e+02	2.6365069e+01
17	2	1.1418544e+01	7.3178642e-01	1.5478263e+00	2.7466315e+07	1.0713718e+02	2.6365069e+01
17	3	1.2134342e+01	9.2673260e-01	1.5691598e+00	2.0032510e+08	5.6750499e+01	1.2742209e+01

Table I. (cont.)

n	l	a	p	α	b	β	ω_m
17	4	1.1195332e+01	1.0740749e+00	1.3814994e+00	6.8150528e+08	3.2450625e+01	6.1582953e+00
17	5	8.1742302e+00	1.1169297e+00	9.6848217e-01	1.2377930e+09	1.9980445e+01	2.9762973e+00
17	6	6.6689921e+00	1.2476669e+00	7.5334461e-01	3.0461580e+09	1.4897299e+01	2.0691130e+00
17	7	8.7856797e+00	1.7508462e+00	9.2684588e-01	9.8274747e+09	1.2475654e+01	2.0691130e+00
17	8	1.0601912e+01	2.3132454e+00	9.5627862e-01	2.0366273e+10	1.0355518e+01	2.0691130e+00
17	9	1.0528524e+01	2.8955608e+00	8.7910731e-01	2.9336066e+10	8.6218431e+00	2.0691130e+00
17	10	8.2787697e+00	3.4864629e+00	7.5211159e-01	3.0772430e+10	7.2366171e+00	2.0691130e+00
17	11	5.1051862e+00	4.0883512e+00	6.1313546e-01	2.3956170e+10	6.1317738e+00	2.0691130e+00
17	12	2.4378343e+00	4.7058040e+00	4.8001960e-01	1.3799010e+10	5.2438329e+00	2.0691130e+00
17	13	8.7520802e-01	5.3419248e+00	3.5916045e-01	5.7400268e+09	4.5221376e+00	2.0691130e+00
17	14	2.2301611e-01	5.9981786e+00	2.5177791e-01	1.6351698e+09	3.9283425e+00	2.0691130e+00
17	15	3.6005620e-02	6.6749672e+00	1.5708301e-01	2.8593438e+08	3.4338704e+00	2.0691130e+00
17	16	2.7699145e-03	7.3721224e+00	7.3660556e-02	2.3165945e+07	3.0174191e+00	2.0691130e+00
18	0	2.3610441e+00	1.8632086e-01	-9.7528542e-02	3.9492119e+03	1.8510514e+02	2.6365069e+01
18	1	7.6242534e+00	4.0616826e-01	5.3464332e-01	7.0620921e+05	1.3920494e+02	2.6365069e+01
18	2	1.1134486e+01	6.9394714e-01	1.4078030e+00	3.6069676e+07	1.1371052e+02	2.6365069e+01
18	3	1.1495752e+01	8.6621916e-01	1.4213378e+00	2.9092125e+08	6.0837276e+01	1.2742209e+01
18	4	1.0378897e+01	9.8920645e-01	1.2398450e+00	1.0826804e+09	3.4975455e+01	6.1582953e+00
18	5	1.1926425e+01	1.2527205e+00	1.3502194e+00	4.6037111e+09	2.4938705e+01	4.2812285e+00
18	6	6.4092071e+00	1.1312392e+00	6.8230589e-01	5.8551351e+09	1.6172512e+01	2.0691130e+00
18	7	8.4669057e+00	1.5972165e+00	8.9860480e-01	2.2920505e+10	1.3724363e+01	2.0691130e+00
18	8	1.0858233e+01	2.1390443e+00	9.8331876e-01	5.6820211e+10	1.1487456e+01	2.0691130e+00
18	9	1.1973197e+01	2.7115000e+00	9.4772952e-01	9.7049326e+10	9.6132938e+00	2.0691130e+00
18	10	1.0710152e+01	3.2944769e+00	8.4280244e-01	1.2081085e+11	8.0954832e+00	2.0691130e+00
18	11	7.6543024e+00	3.8862313e+00	7.1191340e-01	1.1283731e+11	6.8760133e+00	2.0691130e+00
18	12	4.3414019e+00	4.4906800e+00	5.7916679e-01	7.9714829e+10	5.8922151e+00	2.0691130e+00
18	13	1.9238852e+00	5.1114609e+00	4.5499138e-01	4.2199986e+10	5.0911714e+00	2.0691130e+00
18	14	6.4488500e-01	5.7506955e+00	3.4276184e-01	1.6279864e+10	4.4316762e+00	2.0691130e+00
18	15	1.5409271e-01	6.4092788e+00	2.4275037e-01	4.3306862e+09	3.8825310e+00	2.0691130e+00
18	16	2.3407686e-02	7.0873610e+00	1.5403949e-01	7.1106634e+08	3.4202600e+00	2.0691130e+00
18	17	1.6991992e-03	7.7847003e+00	7.5360331e-02	5.4343326e+07	3.0271341e+00	2.0691130e+00
19	0	2.4130883e+00	1.8631329e-01	-1.3443549e-01	4.0291608e+03	1.8481660e+02	2.6365069e+01
19	1	7.7640519e+00	3.9602621e-01	4.6593897e-01	7.8784975e+05	1.4301140e+02	2.6365069e+01
19	2	1.0940440e+01	6.6137657e-01	1.2820552e+00	4.6132129e+07	1.1994331e+02	2.6365069e+01
19	3	1.1037097e+01	8.1468231e-01	1.2876372e+00	4.0749121e+08	6.4753406e+01	1.2742209e+01
19	4	9.7992718e+00	9.1769593e-01	1.1101014e+00	1.6433076e+09	3.7403173e+01	6.1582953e+00
19	5	1.0845028e+01	1.1469735e+00	1.2227059e+00	7.8870375e+09	2.6910052e+01	4.2812285e+00
19	6	1.0915668e+01	1.3641993e+00	1.1665636e+00	2.3826373e+10	1.9800034e+01	2.9762973e+00
19	7	8.0802938e+00	1.4577584e+00	8.5322012e-01	4.9652586e+10	1.4970631e+01	2.0691130e+00
19	8	1.0738823e+01	1.9742423e+00	9.8821884e-01	1.4641894e+11	1.2642684e+01	2.0691130e+00
19	9	1.2862295e+01	2.5341734e+00	9.9787316e-01	2.9416192e+11	1.0638523e+01	2.0691130e+00
19	10	1.2852335e+01	3.1093985e+00	9.2111499e-01	4.2921408e+11	8.9901390e+00	2.0691130e+00
19	11	1.0437678e+01	3.6926664e+00	8.0330774e-01	4.7224958e+11	7.6542834e+00	2.0691130e+00
19	12	6.8472134e+00	4.2861653e+00	6.7423508e-01	3.9841641e+11	6.5715241e+00	2.0691130e+00
19	13	3.6000156e+00	4.8936277e+00	5.4877065e-01	2.5791612e+11	5.6877730e+00	2.0691130e+00
19	14	1.4891823e+00	5.5177292e+00	4.3291615e-01	1.2637623e+11	4.9594036e+00	2.0691130e+00
19	15	4.6822538e-01	6.1598729e+00	3.2833063e-01	4.5462459e+10	4.3527435e+00	2.0691130e+00

Table I. (cont.)

n	l	a	p	α	b	β	ω_m
19	16	1.0532412e-01	6.8205685e+00	2.3478981e-01	1.1343439e+10	3.8421683e+00	2.0691130e+00
19	17	1.5105991e-02	7.4998048e+00	1.5135807e-01	1.7553585e+09	3.4081915e+00	2.0691130e+00
19	18	1.0379726e-03	8.1972986e+00	7.6907751e-02	1.2695220e+08	3.0359108e+00	2.0691130e+00
20	0	2.4657275e+00	1.8663074e-01	-1.6464894e-01	4.0960915e+03	1.8421455e+02	2.6365069e+01
20	1	7.9141165e+00	3.8741106e-01	4.0653440e-01	8.6878347e+05	1.4639461e+02	2.6365069e+01
20	2	1.0815794e+01	6.3318639e-01	1.1692027e+00	5.7648138e+07	1.2583332e+02	2.6365069e+01
20	3	1.3598786e+01	8.7587042e-01	1.5932745e+00	1.0988620e+09	8.4026250e+01	1.8328917e+01
20	4	1.2635435e+01	1.0003227e+00	1.4288459e+00	5.3434690e+09	4.7702954e+01	8.8583454e+00
20	5	1.0050783e+01	1.0566791e+00	1.1011634e+00	1.2865882e+10	2.8827732e+01	4.2812285e+00
20	6	9.9913148e+00	1.2471253e+00	1.0664261e+00	4.3322470e+10	2.1335956e+01	2.9762973e+00
20	7	7.6982013e+00	1.3327783e+00	7.9604884e-01	1.0057664e+11	1.6203900e+01	2.0691130e+00
20	8	1.0381171e+01	1.8199574e+00	9.7359798e-01	3.5115729e+11	1.3813541e+01	2.0691130e+00
20	9	1.3221230e+01	2.3639631e+00	1.0292702e+00	8.2494638e+11	1.1692956e+01	2.0691130e+00
20	10	1.4507219e+01	2.9305927e+00	9.8563815e-01	1.3982248e+12	9.9180998e+00	2.0691130e+00
20	11	1.3175239e+01	3.5063456e+00	8.8587611e-01	1.7884078e+12	8.4653201e+00	2.0691130e+00
20	12	9.8046305e+00	4.0905828e+00	7.6408050e-01	1.7680428e+12	7.2811712e+00	2.0691130e+00
20	13	5.9535101e+00	4.6865375e+00	6.3965235e-01	1.3621953e+12	6.3117219e+00	2.0691130e+00
20	14	2.9200655e+00	5.2972360e+00	5.2161717e-01	8.1436352e+11	5.5115040e+00	2.0691130e+00
20	15	1.1330638e+00	5.9245601e+00	4.1335280e-01	3.7151642e+11	4.8445962e+00	2.0691130e+00
20	16	3.3550670e-01	6.5694036e+00	3.1554437e-01	1.2521435e+11	4.2832907e+00	2.0691130e+00
20	17	7.1293063e-02	7.2320184e+00	2.2771930e-01	2.9418546e+10	3.8063418e+00	2.0691130e+00
20	18	9.6840423e-03	7.9122900e+00	1.4897795e-01	4.3047409e+09	3.3974173e+00	2.0691130e+00
20	19	6.3163855e-04	8.6099149e+00	7.8321960e-02	2.9546319e+08	3.0438779e+00	2.0691130e+00

Table II. Parameters for photoionization and photrecombination of the one-electron states of the FeXVII ion from n= 1 to 8.

n	l	etr(au)	a	p	b	β	ω_m	gff
1	0	2.819e+02	1.036e+00	2.844e+00	3.963e+00	5.825e-01	3.000e+00	1.323e+00
2	0	5.100e+01	1.029e+00	2.247e+00	2.394e+01	1.838e+00	5.528e+00	1.083e+00
2	1	4.693e+01	1.518e+00	3.123e+00	5.530e+01	1.708e+00	6.006e+00	1.392e+00
3	0	1.890e+01	8.925e-01	2.019e+00	4.604e+01	2.663e+00	6.053e+00	8.410e-01
3	1	1.767e+01	1.176e+00	2.325e+00	5.242e+02	3.942e+00	4.281e+00	7.490e-01
3	2	1.607e+01	9.637e-01	3.200e+00	2.172e+02	2.075e+00	2.976e+00	1.124e+00
4	0	9.751e+00	8.697e-01	1.927e+00	1.070e+02	4.601e+00	6.103e+00	7.492e-01
4	1	9.262e+00	1.119e+00	2.158e+00	1.425e+03	5.559e+00	6.108e+00	5.556e-01
4	2	8.635e+00	1.221e+00	2.671e+00	2.920e+02	1.621e+00	2.976e+00	8.585e-01
4	3	8.214e+00	5.450e-01	5.993e+00	2.146e-02	-2.890e+00	6.122e+00	7.219e-01
5	0	5.965e+00	8.795e-01	1.893e+00	1.068e+02	4.372e+00	6.168e+00	6.992e-01
5	1	5.724e+00	1.083e+00	2.024e+00	2.698e+03	6.718e+00	6.175e+00	4.622e-01
5	2	5.418e+00	1.283e+00	2.366e+00	4.051e+03	3.942e+00	2.976e+00	7.153e-01
5	3	5.222e+00	8.393e-01	4.116e+00	2.207e+01	-9.452e-01	6.191e+00	6.712e-01
5	4	5.112e+00	3.672e-01	4.320e+00	7.584e+03	4.560e+00	6.196e+00	7.686e-01
6	0	4.018e+00	9.360e-01	1.923e+00	3.054e+01	1.158e+00	6.249e+00	6.588e-01
6	1	3.890e+00	1.131e+00	1.997e+00	1.413e+03	4.749e+00	6.257e+00	4.009e-01
6	2	3.711e+00	1.376e+00	2.290e+00	2.032e+03	2.625e+00	4.281e+00	6.276e-01
6	5	3.528e+00	2.503e-01	4.501e+00	1.701e+03	1.191e+00	6.283e+00	7.385e-01
6	4	3.550e+00	7.450e-01	3.932e+00	1.671e+03	1.051e+00	6.282e+00	7.280e-01
6	3	3.571e+00	1.094e+00	3.539e+00	4.459e+02	5.746e-01	6.280e+00	6.202e-01
7	0	2.895e+00	9.743e-01	1.893e+00	1.628e+02	5.384e+00	6.345e+00	6.402e-01
7	1	2.816e+00	1.160e+00	1.963e+00	1.904e+03	5.253e+00	6.355e+00	3.726e-01
7	2	2.706e+00	1.460e+00	2.206e+00	2.286e+04	6.094e+00	4.281e+00	5.721e-01
7	5	2.593e+00	5.932e-01	4.222e+00	6.336e+05	6.472e+00	6.386e+00	7.361e-01
7	6	2.589e+00	1.782e-01	5.145e+00	1.942e+05	5.406e+00	6.386e+00	7.553e-01
7	4	2.607e+00	1.045e+00	3.489e+00	5.334e+04	3.670e+00	6.384e+00	7.065e-01
7	3	2.617e+00	1.281e+00	3.174e+00	1.003e+04	3.439e+00	6.382e+00	6.055e-01
8	0	2.185e+00	1.009e+00	1.913e+00	6.168e+01	2.521e+00	6.458e+00	6.474e-01
8	1	2.133e+00	1.186e+00	1.928e+00	6.541e+03	8.627e+00	6.469e+00	3.499e-01
8	2	2.060e+00	1.531e+00	2.197e+00	9.660e+04	9.260e+00	6.158e+00	5.314e-01
8	5	1.985e+00	8.846e-01	3.895e+00	3.727e+06	7.688e+00	6.504e+00	7.256e-01
8	6	1.983e+00	4.467e-01	4.789e+00	2.030e+06	6.399e+00	6.504e+00	7.467e-01
8	4	1.995e+00	1.231e+00	3.263e+00	9.929e+04	3.684e+00	6.501e+00	6.759e-01
8	7	1.982e+00	1.155e-01	5.391e+00	1.807e+06	6.164e+00	6.504e+00	7.541e-01
8	3	2.000e+00	1.369e+00	2.916e+00	8.241e+03	2.333e+00	6.500e+00	5.787e-01